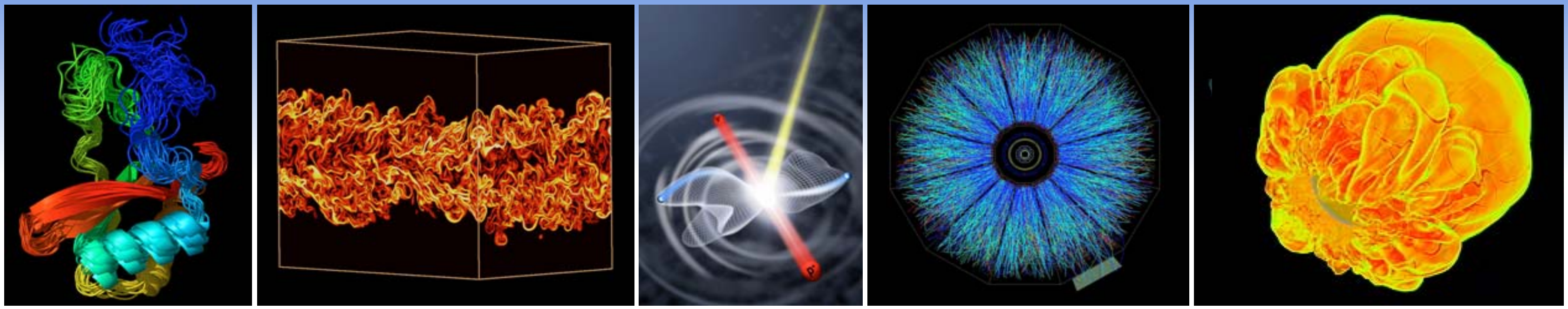


Computing Sciences at Berkeley Lab

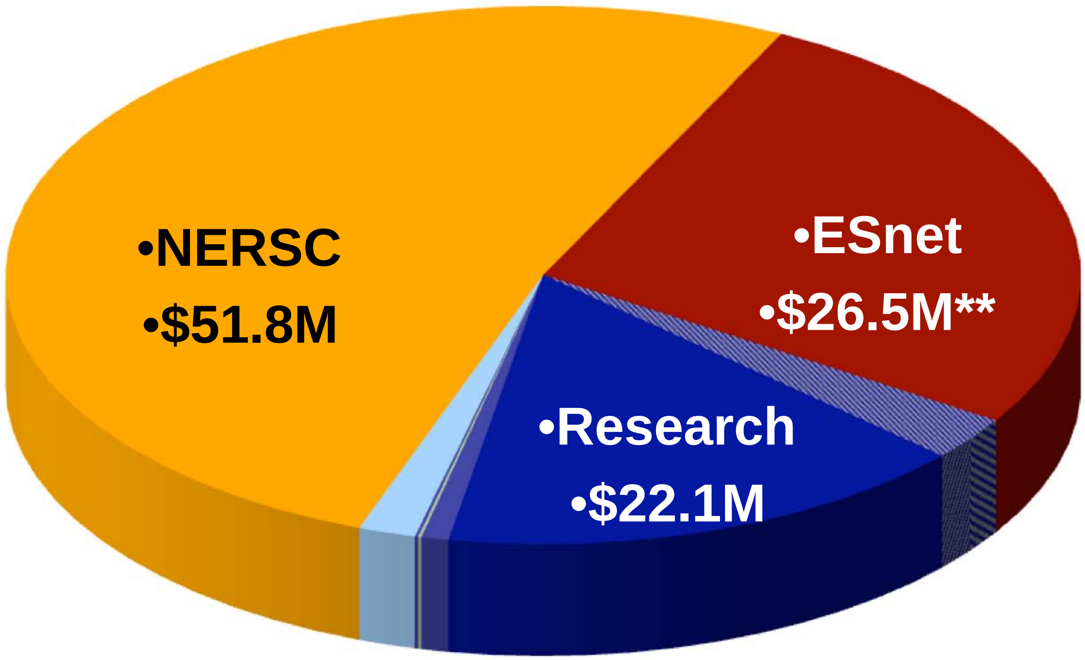
Katherine Yelick
NERSC Director

Computing Sciences Mission

- **Deliver world class facilities, NERSC and ESnet, supporting the DOE Office of Science computational mission**
- **Conduct world class research in applied mathematics and computer science in support of DOE science mission**
- **Build and maintain an outstanding computational science and engineering (CSE) research effort in close collaboration with the UC campuses**

Computing Science Programs

$100.3M Annual Budget in FY09*



•*$3M deducted from FY09 NERSC budget for funds received in FY08

•** ESnet includes 3.2M for services provided to other sites through IWOs

COMPUTING SCIENCES DIRECTORATE

HORST SIMON
Associate Laboratory Director for Computing Sciences

CS DEPUTY
Michael Banda

- BUSINESS MANAGEMENT
- COMMUNICATIONS
- FACILITIES AND EH&S
- HUMAN RESOURCES

NATIONAL ENERGY RESEARCH SCIENTIFIC COMPUTING (NERSC) DIVISION

KATHY YELICK
Division Director

HOWARD WALTER
Division Deputy

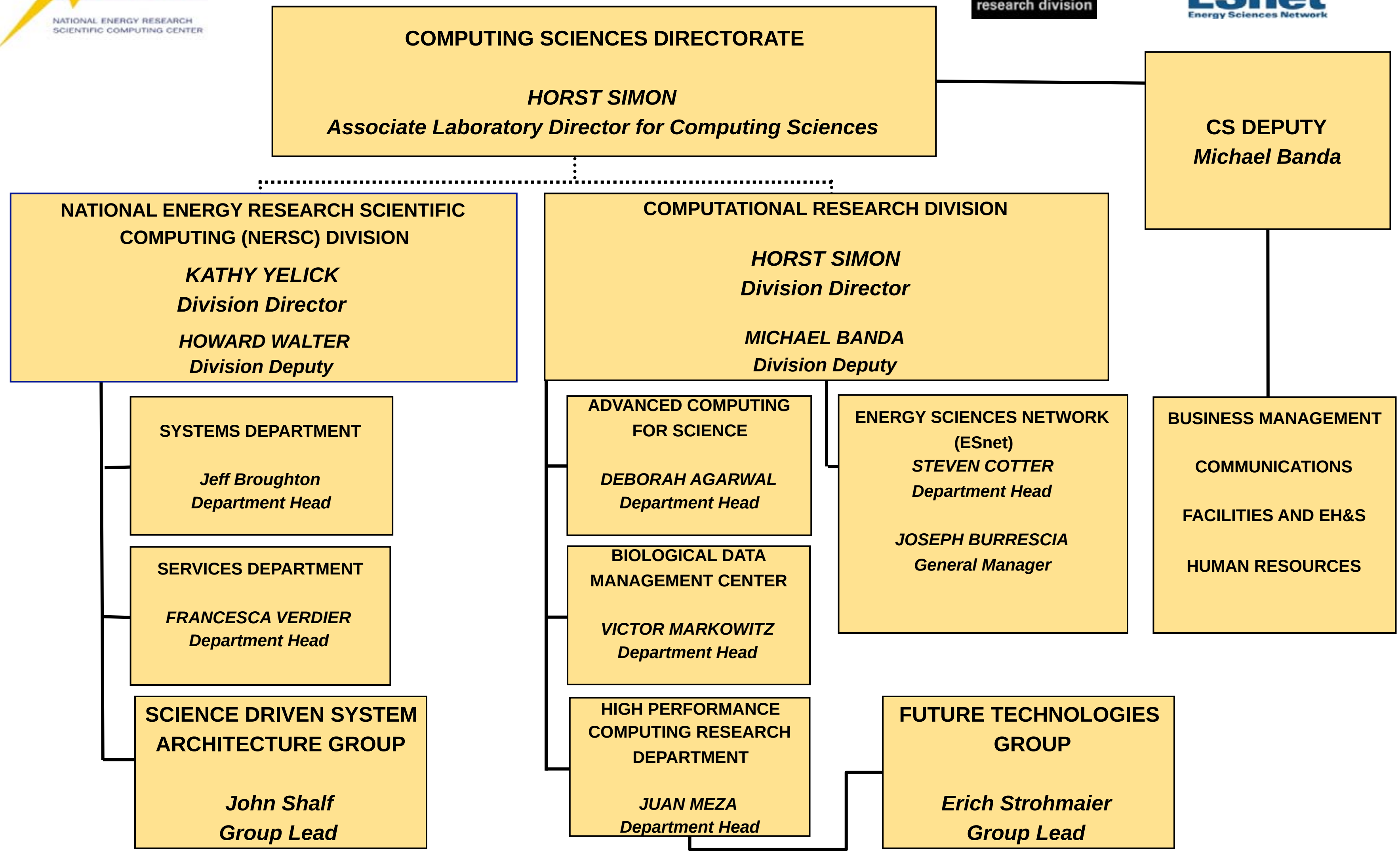
- SYSTEMS DEPARTMENT
  Jeff Broughton
  Department Head
- SERVICES DEPARTMENT
  FRANCESCA VERDIER
  Department Head

COMPUTATIONAL RESEARCH DIVISION

HORST SIMON
Division Director

MICHAEL BANDA
Division Deputy

- ADVANCED COMPUTING FOR SCIENCE
  DEBORAH AGARWAL
  Department Head
- BIOLOGICAL DATA MANAGEMENT CENTER
  VICTOR MARKOWITZ
  Department Head
- HIGH PERFORMANCE COMPUTING RESEARCH DEPARTMENT
  JUAN MEZA
  Department Head
- ENERGY SCIENCES NETWORK (ESnet)
  STEVEN COTTER
  Department Head
  JOSEPH BURRESCIA
  General Manager



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HUMAN RESOURCES
FUTURE TECHNOLOGIES GROUP
Erich Strohmaier
Group Lead

Overview of the Berkeley UPC Project

UPC Project Goals

2001-2004: A Portable UPC Compiler

- UPC was (incorrectly) viewed as a language that required shared memory hardware or only ran on Cray machines
- The Berkeley UPC compiler showed it could run on clusters with a lightweight runtime and that source-to-source translation was reasonable

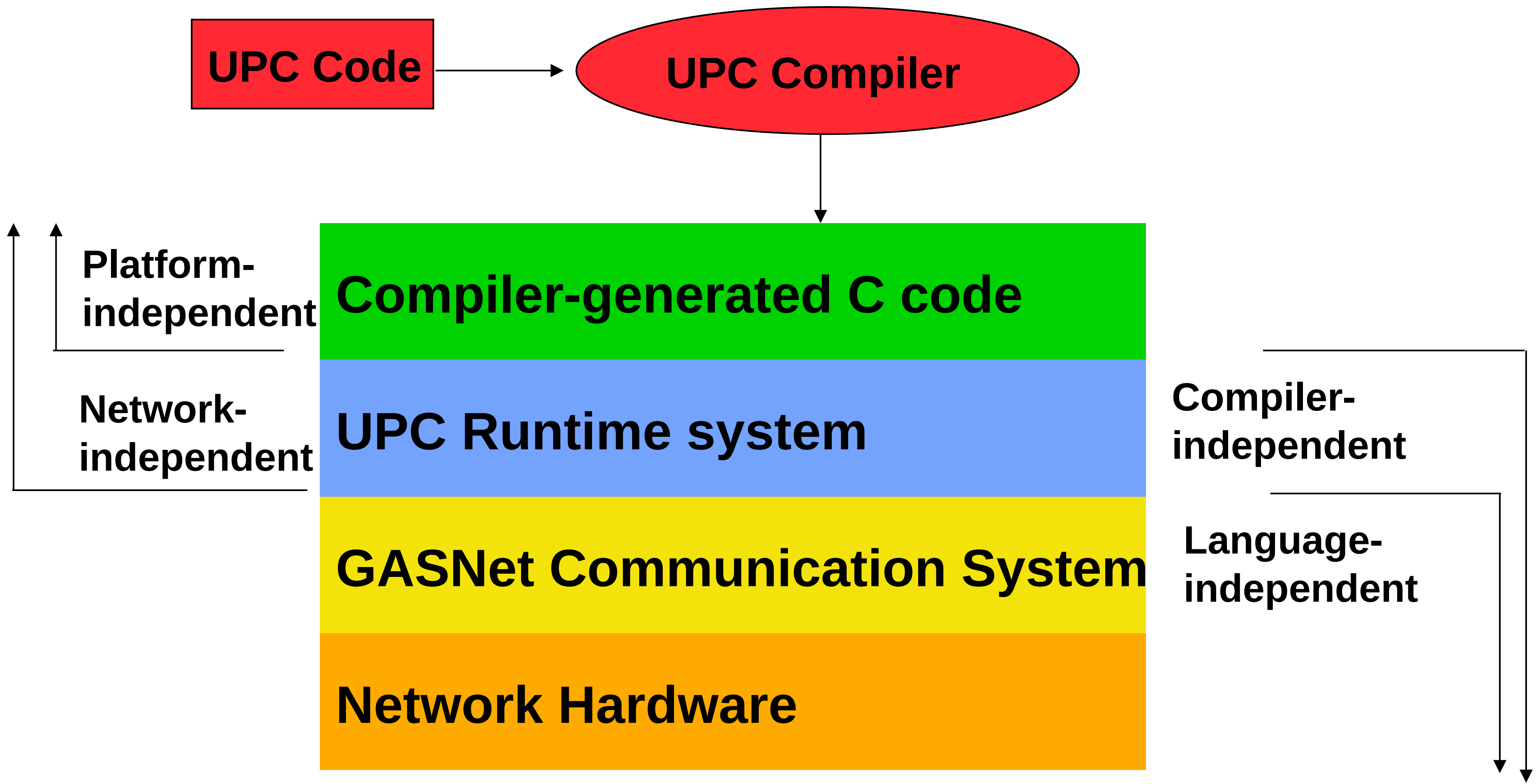
2005-2008: UPC is a High Performance Language

- Conventional wisdom: UPC is more productive than MPI but we should expect it to be slower (maybe by 2x)
- Even on clusters without global address space support, UPC can outperform MPI on microbenchmarks and apps

2008-2010: UPC for multicore & hybrid multicore / clusters

- Are either MPI / core or OpenMP within a node “good enough”?
- UPC should be better: lower memory footprint, better locality contol

Berkeley UPC Compiler



Berkeley UPC Compiler Highlights

- Portable, high-performance open-source UPC compiler
  - Fully UPC spec compliant
  - Includes UPC collectives and UPC-I/O
- Many extensions for performance and programmability
  - Non-blocking and non-contiguous memcpy functions
  - Semaphores and signaling put
  - Fine granularity timers
  - Value-based collectives
  - Atomic memory operations
  - Hierarchical layout query
  - Call to/from MPI (C++, F, etc.)
- Entirely free & open source
  - Available from http://upc.lbl.gov
  - Also in CDs at SC each year

New in November 2008 Release

- Native support for IBM BlueGene/P (dcmf conduit)
- Cray Portals network upgrade to cache local memory registration
- Many small improvements to IBM LAPI support
- Improvements in Myrinet GM support
- InfiniBand support for InfiniPath adapters
- Experimental support for ARM processors
- MIPSEL/Linux (SiCortex) support (alas)
- Fine-grained programs optimizations
  - split-phase, access coalescing
- Beta release of “vectorization”
- Pathscale Compiler support
- Many bug fixes

Multicore (and Accelerator) Plans

- **Performance is often non-obvious**
  - E.g., MPI faster than threads on an SMPs
- **Multiple runtime approaches**
  - SMP runtime system based on Pthreads (old)
    - Some work to pin threads and get memory affinity for NUMA
    - Some overhead for thread-local (globally scoped) data
  - Run a GASNet conduit with processes
    - High overhead for communication, but good data partitioning
  - Processes with some form of OS-supported shared memory
    - Prototype done by Jason Duell, but only for a single node
    - More from Filip today
- **Partitioned memory space (GPUs, Cell, etc.)**
  - Some work on this by Filip for Cell
  - More ideas from Yili and rest of the group

Collective Communication

- **Important for many scientific applications**
  - Productivity and performance enhancer
  - Teams are critical: more on this later by Yili
- **Collectives for clusters**
  - Work with IBM, data centric
  - New work: completely re-designed and re-built collectives
  - Some improvements in Nov 08 release, more coming
- **Collectives for Multicore**
  - Surprisingly important, even for barriers
- **Autotuned collectives (Yili and Rajesh)**
  - Taking the pain out of tuning

GASNet

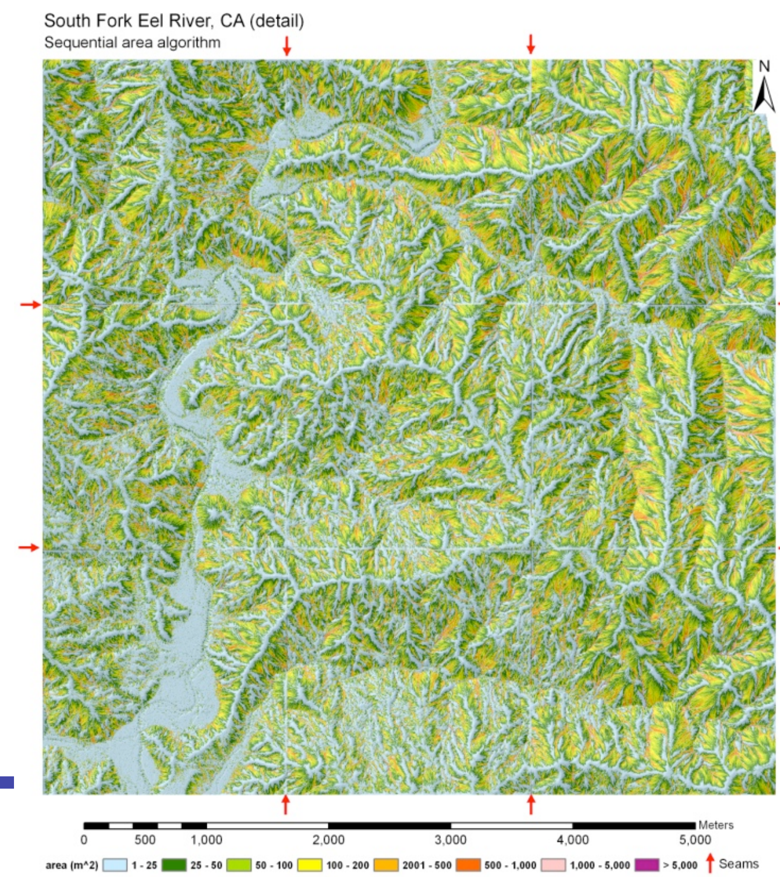
- **Focus on BG/P conduit (Rajesh)**
  - Scaling work on Intrepid machine at Argonne (ALCF)
- **Cray Portals conduit (Paul)**
  - Several bug fixes and performance improvements
  - Ongoing benchmarking work on Franklin machine at NERSC and others
- **Infiniband**
  - Ongoing bug fixed and performance improvements
  - Work specifically on scaling for Ranger machine at TACC

UPC Applications from LBNL

- **UPC applications stress global address space:**
  - irregular remote memory accesses
  - need for low overhead communication
- **Delaunay mesh generation**
- **Adaptive Mesh Refinement**
- **Sparse Cholesky factorization**
- **Biology application**
- **Dense LU factorization with event-driven execution**
- **Latest one: Landscape evolution (NSF PetaApps Climate project)**

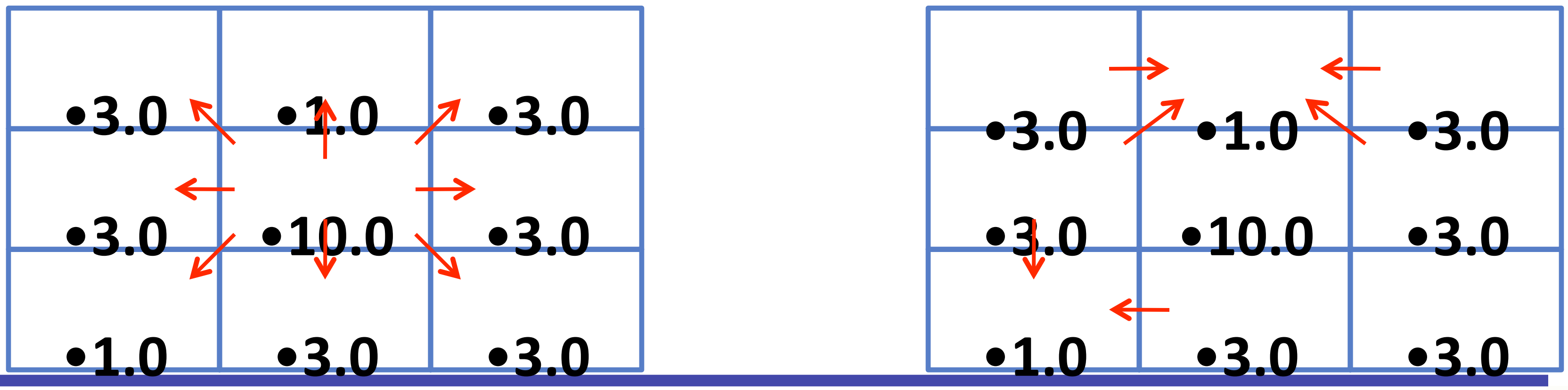
Landscape Evolution

- **How to evolve landscapes over time?**
  - Erosion, rainfall, river incision
- **Area distribution**
  - Want to parallelize this
- **Input series of tiles**
  - Vast input range
  - Serial seams



Area Distribution Algorithm

- **Analogous to precipitation distribution**
  - Each cell seeded with an initial area distribution
  - Area "distributed" proportionally to downhill neighbors based on elevation
- **Originally a recursive, serial algorithm**
  - Changed to a scatter operation for parallel implementation

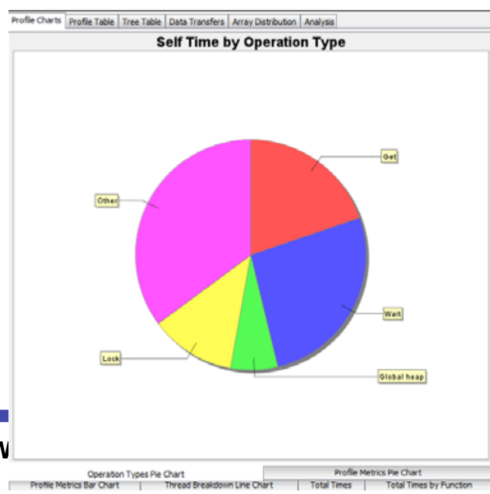


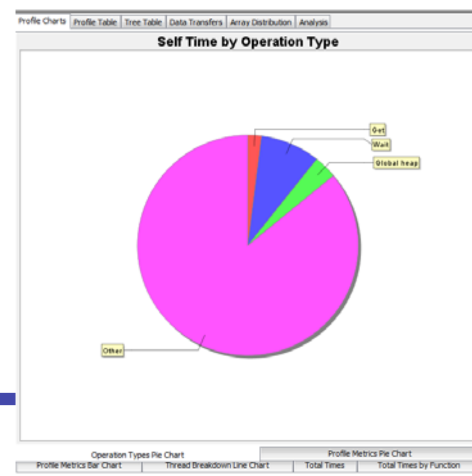
UPC Implementation

- **Input elevation tiles stored in global shared array**
  - Threads split input tiles with horizontal stripes
- **Information shared after collecting all uphill data**
  - Reduces communication across threads
  - Queues used to push/pop information to/from remote threads
- **Threads alternate work between local/remote queues to improve throughput**
- **Computation ceases once all cells have pushed data**

Implementations

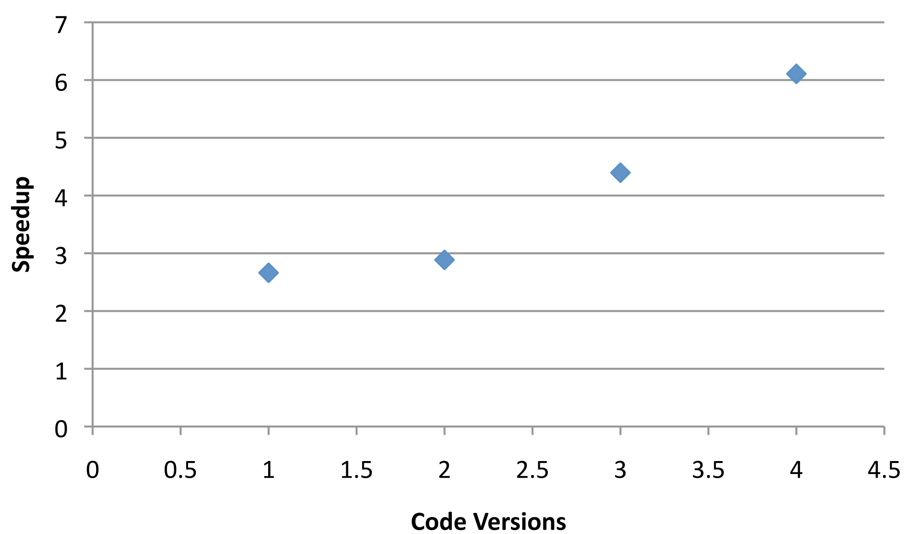
- **Original implementation was very inefficient**
  - Remote variables, upc_locks, non-local queues
- **PPW helpful in locating areas of inefficiency**
  - Indicated areas in source with unexpected communication
  - UPC functions comprised > 60% of runtime





Optimizations

- **V 1 – Optimized parallel base-code**
- **V 2 – Remote queues local to data owner**
- **V 3 – Replaced queues with dynamic arrays for local computation**
- **V 4 – Replaced UPC locks with semaphores**



Tests performed with eight 2km x 2km tiles and eight threads

Analysis

- **Speedup capped by topography**
  - In worst case, performance could be less than serial code
  - In best case, with minimal computation, can achieve a speedup of 7.1 for prior test case
- **Eliminating UPC locks gave best results in terms of scalability**
- **PPW helpful for pinpointing areas for improvement**
- **Running algorithm in parallel is only way to achieve the true results**

9:00 a.m.	Overview of Computing Sciences and Berkeley UPC Project	Kathy Yelick
9:30 a.m.	Berkeley Compiler Update	Costin Iancu
10:00 a.m.	Intrepid Compiler Update	Gary Funck
10:30 a.m.	Break	
10:45 a.m.	Team Collectives and BG/P Results	Yili and Rajesh
11:30	GASNet on Cray Portals	Paul Hargrove
12:00 p.m.	Working Lunch	
	Process-Based SMP Runtime	Filip Blagojevic
1:00 p.m.	Autotuned Multicore Collectives	Rajesh Nishtala
1:30 p.m.	Resource Management for Multicore	Costin Iancu
2:15 p.m	Compiling Shared Memory programs for GPUs	Seung-Jai Min
2:40 p.m.	UPC Ideas for GPUs / Accelerators	Yili Zheng
3:15 p.m.	Break	
3:30 p.m.	Irregular Communication Optimizations in PGAS	Jimmy Su
4:00 p.m.	Irregular Memory Optimizations on Multicore	Kamesh Madduri
4:30 p.m.	Future Plans	Kathy Yelick